

Original Paper

# Assessing the Effectiveness of Interactive Robot-Assisted Virtual Health Coaching for Health Literacy and Disease Knowledge of Patients with Chronic Kidney Disease: Quasiexperimental Study

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## Abstract

**Background:** Chronic kidney disease (CKD) imposes a significant global health and economic burden, impacting millions globally. Despite its high prevalence, public awareness and understanding of CKD remain limited, leading to delayed diagnosis and suboptimal management. Traditional patient education methods, such as 1-on-1 verbal instruction or printed brochures, are often insufficient, especially considering the shortage of nursing staff. Technology-assisted education presents a promising and standardized solution, emphasizing the need for innovative and scalable approaches to improve CKD-specific knowledge and health literacy.

**Objective:** This study aimed to develop and evaluate the effectiveness of an innovative 12-unit virtual health coaching program delivered through interactive robots that is intended to enhance disease knowledge and health literacy among patients with CKD.

**Methods:** A quasiexperimental design was used, and 60 participants were evenly assigned to experimental and comparison groups. However, due to attrition, 14 participants in the experimental group and 16 participants in the comparison group completed the study. The intervention involved a 12-unit program, with each unit lasting approximately 20 minutes to 30 minutes and delivered across 3 to 4 learning sessions, and participants completed 3 to 4 units per session. The program addressed key aspects of CKD-specific health literacy including functional, communicative, and critical literacy and CKD-specific knowledge including basic knowledge, prevention, lifestyle, dietary intake, and medication. Data were collected through validated pre and postintervention questionnaires. All 30 participants completed the program and subsequent evaluations, with outcome measures assessing changes in CKD-specific knowledge and health literacy.

**Results:** Postintervention analysis using generalized estimating equations, adjusted for age, revealed that the experimental group ( $n=14$ ) had significantly greater improvements in health literacy (coefficient=2.51, Wald  $\chi^2_1=5.89$ ;  $P=.02$ ) and disease knowledge (coefficient=1.66, Wald  $\chi^2_1=11.75$ ;  $P=.001$ ) than the comparison group ( $n=16$ ). Postintervention  $t$  tests revealed significant improvements in CKD-specific health literacy and disease knowledge ( $P<.001$ ) between the experimental and comparison groups. Additional analyses identified significant group  $\times$  time interactions, indicating improvements in communicative literacy ( $P=.01$ ) and critical literacy ( $P=.02$ ), while no significant changes were observed in functional literacy. Regarding disease knowledge, the experimental group demonstrated a significant improvement in medication ( $P<.001$ ), whereas changes in basic knowledge, prevention, lifestyle, and dietary intake were not significant.

**Conclusions:** This study demonstrated that interactive robot-assisted eHealth coaching effectively enhanced CKD-specific disease knowledge and health literacy. Despite the challenges posed by the COVID-19 pandemic, which constrained sample sizes, the findings indicate that this program is a promising patient education tool in clinical nephrology. Future research should involve larger sample sizes to enhance generalizability and examine additional factors influencing effectiveness.

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## KEYWORDS

chronic kidney disease; disease knowledge; eHealth; health coaching; health education; health literacy; interactive robot

## Introduction

Chronic kidney disease (CKD) has emerged as a major global health issue, with current estimates indicating that it affects approximately 10% of the global population [1]. The disease imposes a significant financial burden driven by the high costs of diagnosis, treatment, and ongoing care. As CKD advances, over two-thirds of patients with CKD experience complications such as cardiovascular disease, metabolic bone disorders, anemia, and malnutrition, all of which can profoundly affect their health and quality of life [2]. In Taiwan, CKD accounts for 7.14% of the nation's total health care expenditure [3], underscoring the critical need for effective prevention strategies. The prevalence of dialysis among patients with CKD in Taiwan underscores the need for targeted interventions. In 2021, only 3.7% of dialysis patients were aged younger than 40 years, while 40.1% were aged 40 years to 64 years, 31.1% were aged 65 years to 74 years, and 25.1% were 75 years old or older. This distribution highlights that the majority of patients with CKD in Taiwan are middle-aged or older.

Health literacy (HL) is defined as the ability to access, understand, evaluate, and apply health information to make informed health decisions [4]. In this study, HL refers to a patient's capacity to comprehend and use CKD management information to manage their CKD [5]. According to Nutbeam [6], HL consists of 3 components: functional, communicative and interactive, and critical literacy. Functional literacy encompasses the basic reading and writing skills needed for everyday functioning. Communicative literacy includes more advanced skills that enable individuals to actively engage in social contexts, extract information, and adapt to changing environments. Critical literacy involves using advanced cognitive and social skills to critically analyze information and exert greater control over personal health and life situations. Limited HL in patients with CKD has been linked to poor health outcomes and reduced treatment adherence [7]. CKD-specific HL and knowledge can help patients manage their condition effectively. In this study, disease-specific knowledge encompassed an understanding of kidney function, disease prevention, healthy lifestyle habits, diet, and medication. Higher

HL levels have been identified as strong predictors of adherence to medication, diet, fluid intake, and general self-management practices [8]. A previous study suggested that complications related to kidney disease may stem from insufficient health knowledge and that HL significantly influences self-care behaviors [9]. One review highlighted that disease-specific knowledge is critical for HL, which is a prerequisite for the effective self-management of CKD [8]. Improving HL can enhance disease knowledge, promote better self-care behaviors, and potentially slow disease progression. These findings underscore the importance of HL and knowledge of kidney disease management.

Health coaching is an evidence-based approach that enables patients to make lasting behavioral changes that enhance their overall health [10]. By offering health care options tailored to individuals' lifestyles and abilities, health coaching improves outcomes, especially among those with chronic illnesses or those at a higher risk of medication nonadherence. Previous studies have shown that health coaching can lead to positive behavioral changes and improved health outcomes in patients with chronic conditions, underscoring its value in managing long-term health [11,12].

Previous studies have demonstrated the significant impact of health promotion and education programs on patients with CKD [13]. Recent digital health intervention advancements, such as wearable devices, virtual reality, and mobile health apps, have introduced innovative approaches to enhance patient education. Wearable devices facilitate self-management by providing personalized information [14], virtual reality enhances CKD education through experiential learning [15], and mobile apps can improve disease knowledge when compared with traditional education alone [16]. Digital technologies for health coaching offer older adults support for improving various health determinants [17], and approaches such as e-learning and remote monitoring have been shown to boost treatment effectiveness and quality of life [18]. Moreover, research has also underscored the need for digital coaching to be user-friendly, highly engaging, and tailored to individual needs [19,20]. Health care professionals face challenges due to insufficient nursing staff, and CKD is a complex condition requiring comprehensive

education. Most education systems rely on traditional methods (eg, brochures or 1-on-1 verbal counseling) that often lack diverse directions and interactions. This gap highlights the urgent need for innovative digital solutions to enhance CKD-specific HL and disease knowledge. Using emerging technologies (eg, interactive robots) that follow official health education guidelines [21] offers a novel solution to standardize education, address staffing shortages, and improve the overall interactivity of CKD education. These technologies can provide personalized and accessible learning experiences, as well as improve patient engagement and outcomes [22].

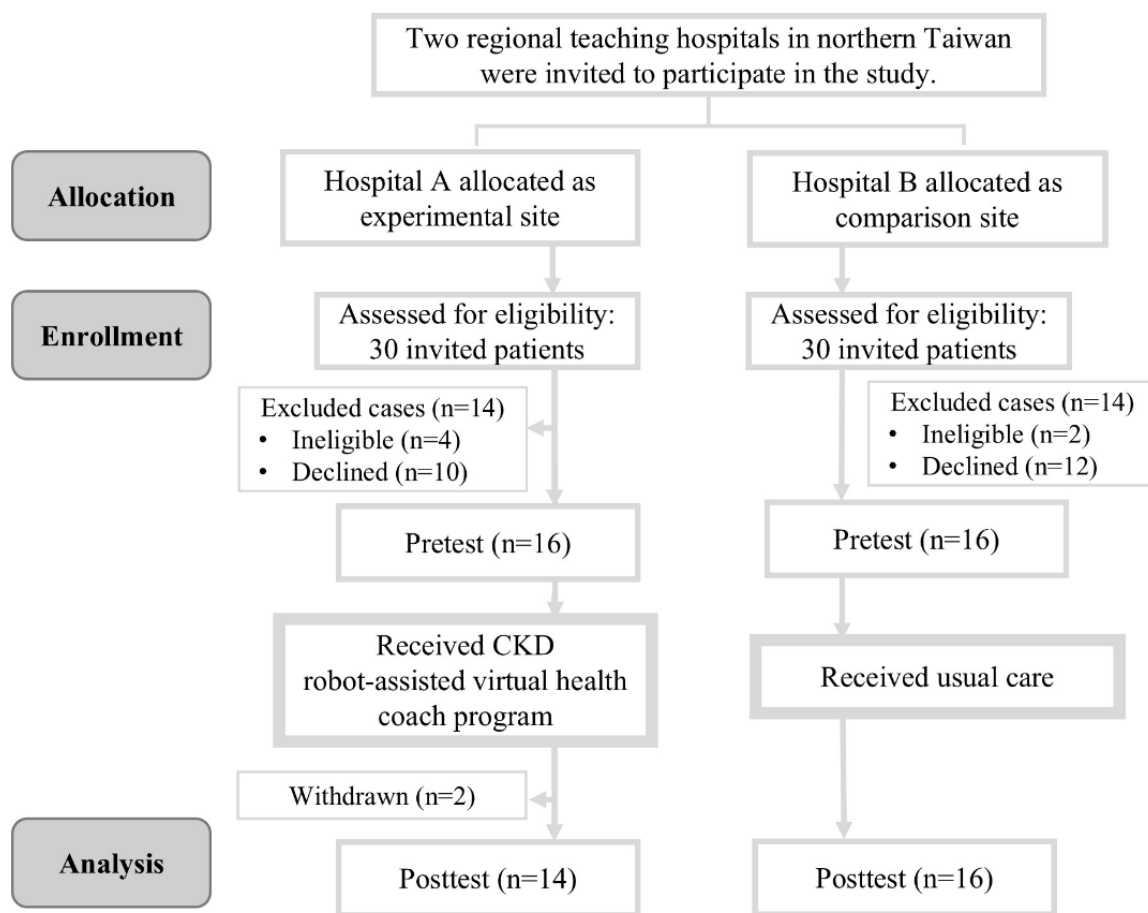
This study aimed to evaluate the effectiveness of an interactive robot-assisted virtual health coaching intervention for improving CKD-specific HL and disease knowledge. The following research questions guided the study: (1) How comprehensively does this intervention improve CKD-specific knowledge? (2) How effective is the intervention in enhancing CKD patients' HL? Prototypes were developed using insights from nephrologists and nurse practitioners who served as virtual health coaches and incorporated their clinical interactions with patients. By offering an engaging and accessible educational platform, the intervention aimed to enhance patient engagement and ultimately improve the health outcomes of patients with CKD.

## Methods

### Study Design

This study adopted a quasiexperimental design involving the recruitment of patients with CKD from the nephrology departments of 2 regional hospitals in northern Taiwan that are similar in size and scope. Each hospital was assigned to either an experimental or comparison group. Health care professionals initially screened patients based on the eligibility criteria and referred interested parties to the research team. This process continued until 30 participants were selected from each hospital. However, due to the COVID-19 pandemic, only 14 participants in the experimental group and 16 participants in the comparison group completed the study. Participant attrition was primarily attributed to the lengthy intervention period and pandemic-related disruptions. Participants in the experimental group received both intervention and usual care provided by nurse practitioners, whereas those in the comparison group received only usual care. During recruitment, the researchers explained the use of the interactive robot and the basic interface operations required. After obtaining written informed consent, the participants were provided with an operation manual and guidance regarding the use of the interface. The flowchart of this study is presented in Figure 1.

Figure 1. Flowchart of the study. CKD: chronic kidney disease.



## Study Population

The inclusion criteria required participants to be adults aged 20 years or older with a diagnosis of CKD. The exclusion criteria included dialysis, transplantation, severe mental illness, dementia, or significant sensory impairments. Patients undergoing dialysis were excluded because of significant differences in care standards and intensity compared with CKD management [23].

## Intervention

An interdisciplinary team including 2 nephrologists and nurse practitioners developed a 12-unit health coaching program using the interactive robot Kebbi Air S (NUWA Robotics Corp). The Kebbi robot, known for its versatility and interactivity, has been used across various domains, including education, health care, and customer service [24]. Prior studies have investigated its effectiveness for language learning and social assistance in health-related contexts and the impact of its expressions on participant engagement [25-27]. The program was designed using government-developed guidelines to ensure standardization and validity [21] after incorporating clinical experiences, patient interactions, and insights from 14

development meetings. These physicians and nurse practitioners acted as virtual health coaches through the robot, delivering content through dialogue, animations, and interactive tasks using artificial intelligence and natural language processing to facilitate dynamic patient engagement. The intervention was conducted using participant-staff 1-on-1 sessions during which staff guided participants in familiarizing themselves with the interface and provided assistance as needed. The robot was programmed to emulate health care professionals' tone and demeanor, offering positive reinforcement (praise, encouragement, and motivational gestures) to sustain patient engagement. Correct answers on standardized quizzes were rewarded with applause, while supportive hints and explanations were provided after incorrect responses to facilitate learning. Virtual health coaches presented information tailored to the 5 stages of CKD, responded to patient inputs, and provided feedback. The program covered critical areas of CKD-specific HL, including functional, communicative, and critical literacy as well as CKD-specific knowledge, including basic knowledge, prevention, lifestyle, dietary intake, and medication. Table 1 provides an overview of the course learning objectives and corresponding outcome variables. Figure 2 illustrates an example of the program's interface.

**Table 1.** Learning objectives and outcome variables of the intervention program.

Unit	Learning objectives	Outcome variables
1	Understand the importance of CKD <sup>a</sup> self-management Know how to measure waist circumference	HL <sup>b</sup> : functional literacy Knowledge: lifestyle
2	Recognize CKD clinical symptoms Identify 5 warning signs of CKD	HL: critical literacy Knowledge: basic knowledge, prevention
3	Understand the importance of regular tracking Know 3 basic types of renal tests	HL: functional literacy Knowledge: prevention
4	Understand the 5 stages of CKD care Know how to calculate eGFR <sup>c</sup> Learn the self-test for renal function	HL: functional literacy Knowledge: lifestyle, prevention
5, 6, 7	Understand nutrition for CKD Identify high-potassium fruits and cooking methods	HL: communicative, functional literacy Knowledge: dietary intake
8	Understand the management of comorbidities of CKD Learn about health care for CKD comorbidities	HL: critical literacy Knowledge: basic knowledge, medication
9	Understand symptoms and self-management of chronic renal failure Learn about psychological adaptations to CKD	HL: communicative literacy Knowledge: basic knowledge, medication
10	Understand the proper time for dialysis Learn the patient-physician shared decision-making strategies	HL: communicative literacy Knowledge: prevention, medication
11	Understand hemodialysis access methods Know arteriovenous fistulas and grafts	HL: critical literacy Knowledge: medication
12	Identify the emergency medical primetime <sup>d</sup> Learn how to rebuild life after CKD	HL: critical literacy Knowledge: lifestyle, medication

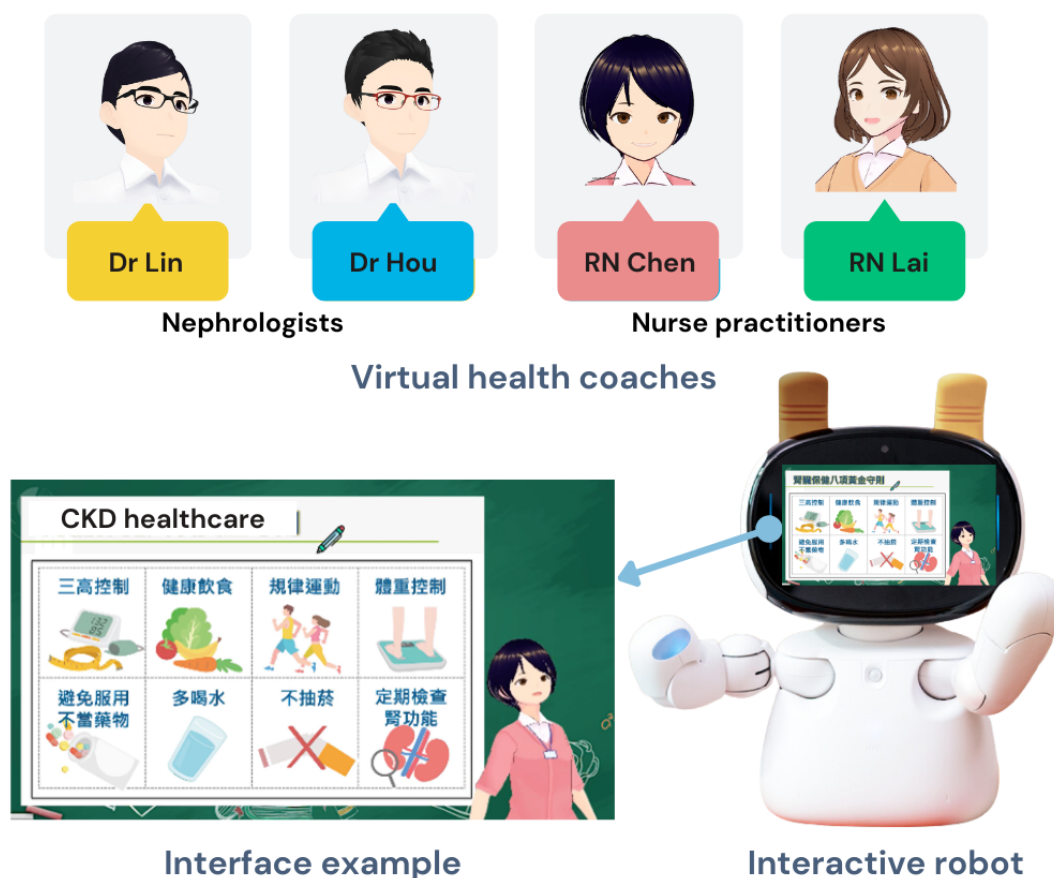
<sup>a</sup>CKD: chronic kidney disease.

<sup>b</sup>HL: health literacy.

<sup>c</sup>eGFR: estimated glomerular filtration rate.

<sup>d</sup>The "Golden Hour" or critical period of time between the time a medical service (such as an ambulance or emergency service) receives a call for help and the arrival of the first emergency team at the scene of an emergency.

**Figure 2.** Interface example of the interactive robot-assisted virtual health coach program for chronic kidney disease (CKD). RN: registered nurse.



## Procedure and Program Delivery

The research team selected an experimental hospital and collaborated with attending nephrologists to define the goals, procedures, and protocols of the study. Upon receiving the hospitals' approval to conduct the study, recruitment posters were distributed to encourage patients with CKD to participate, while an orientation session introduced participants to the study's objectives and collaborative framework. Data collection involved 1-on-1 interviews, enabling in-depth interactions and ensuring that participants were fully engaged with the intervention. Patients were encouraged to interact with the robots to become familiar with the interface. The experimental group participated in a 12-unit intervention, with each unit lasting approximately 20 minutes to 30 minutes. Participants completed 3 to 4 units per session across 3 to 4 learning sessions. The comparison group received usual care, including personalized education, from nurse practitioners. Structured questionnaires were used for the pre and postintervention assessments.

## Measurements

The effectiveness of the intervention was assessed using a validated questionnaire [5,28]. The CKD-specific HL scale and CKD-specific disease knowledge scale were adapted from validated tools specifically designed to assess HL and disease knowledge in patients with CKD. The CKD-specific HL scale includes 17 items for functional, communicative, and critical

literacy in a multiple-choice test format. The CKD-specific disease knowledge scale has 13 true or false items across 5 domains. Higher scores indicated better HL and knowledge. The Cronbach coefficients were 0.78 and 0.76 for the CKD-specific HL scale and the CKD-specific disease knowledge scale, respectively.

## Data Analysis

Data were analyzed using SPSS version 23.0 (IBM Corp). This study primarily aimed to evaluate the intervention's effectiveness at enhancing CKD-specific HL and disease knowledge. No significant differences were found after comparing the pretest scores of the outcome variables between the experimental and comparison groups using *t* tests, eliminating the need to control for the pretest scores. However, due to missing data for some variables, generalized estimating equations (GEEs) were used to analyze the pre and posttest results between the 2 groups while also controlling for age differences. The GEE approach was selected because it effectively handles repeated measures and correlated data, making it well-suited for our study design. It is robust and accommodates missing values, providing reliable estimates and enhancing the validity of our findings.

## Ethical Considerations

This study was approved by the Joint Institutional Review Board of Shin Kong Wu Ho-Su Memorial Hospital (approval number

20211202R) and Cardinal Tien Hospital (approval number CTH-110-3-5-002). All participants were fully informed and provided their consent before the interviews began.

## Results

### User Demographics

The demographic characteristics of participants in the experimental (n=14) and comparison (n=16) groups were not significantly different in gender ( $\chi^2_{28}=0.27$ ;  $P=.61$ ), marital

status ( $\chi^2_{28}=0.05$ ;  $P=.82$ ), and educational level ( $\chi^2_{28}=0.20$ ;  $P=.65$ ), although the experimental group was significantly younger.

### Evaluation Outcomes

As shown in Figure 3, the results of the *t* tests indicated that the posttest scores for CKD-specific HL ( $t_{27}=-4.44$ ;  $P<.001$ ) and disease knowledge ( $t_{28}=5.58$ ;  $P<.001$ ) were significantly higher in the experimental group than in the comparison group.

**Figure 3.** Comparison of pre and posttest (A) CKD-specific health literacy and (B) CKD-specific disease knowledge, reported as the mean (95% CI) scores, with comparisons of pre and postintervention scores between the groups.

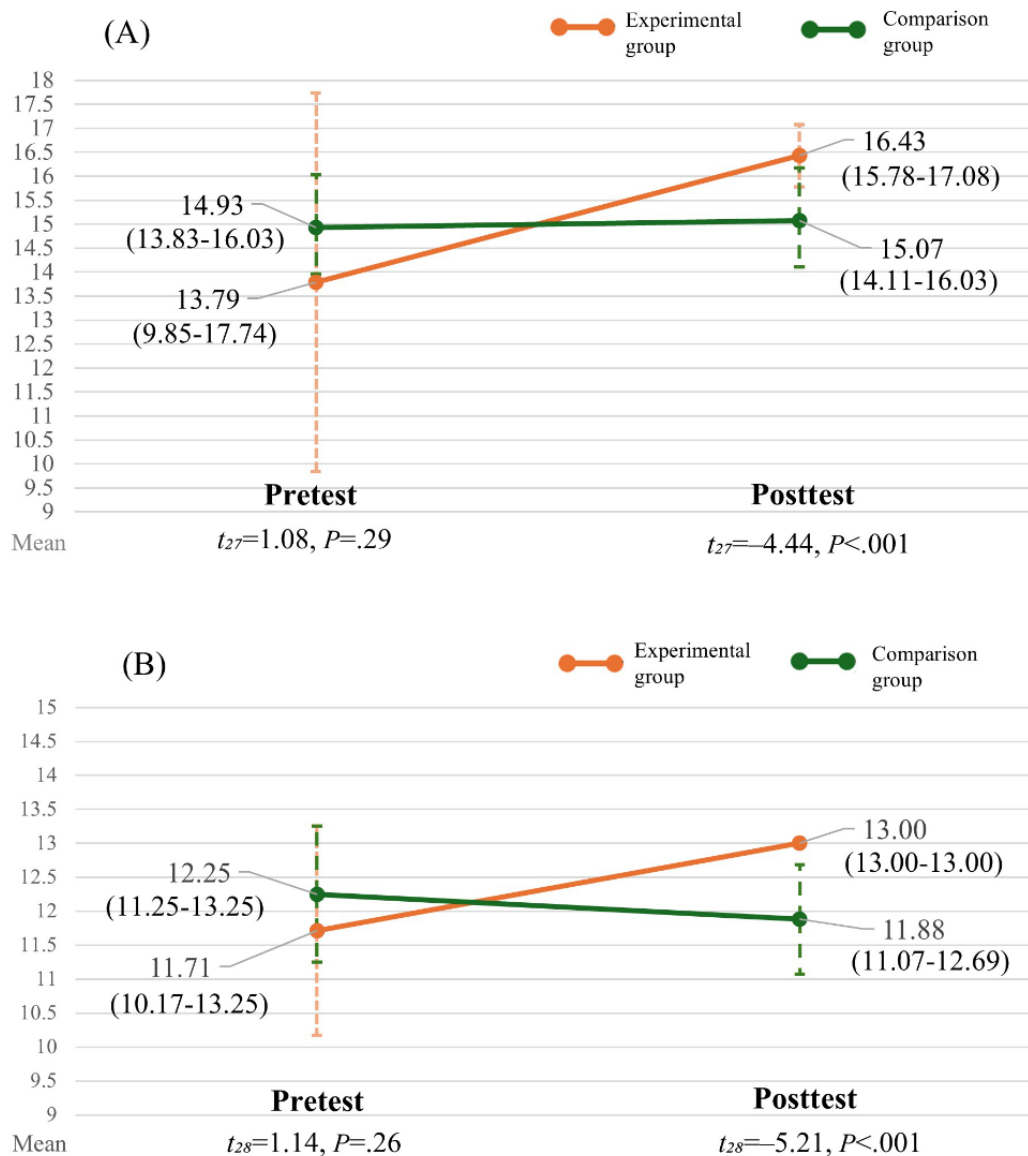


Table 2 shows how both groups' results changed over time. After age adjustment, the GEE analyses demonstrated significant improvements in CKD-specific HL ( $P=.02$ ) and disease knowledge ( $P=.001$ ) in the experimental group compared with the comparison group. A significant group  $\times$ time interaction

was observed for both CKD-specific HL and disease knowledge. Specifically, the experimental group showed improvements in HL (coefficient=2.51, Wald  $\chi^2_1=5.89$ ;  $P=.02$ ) and disease knowledge (coefficient=1.66, Wald  $\chi^2_1=11.75$ ;  $P=.001$ ).

**Table 2.** Results of the generalized estimating equation (GEE) analyses for outcome variables.

Variable	Coefficient ( $\beta$ )	SE	Wald $\chi^2$ (df)	P value
<b>CKD<sup>a</sup>-specific health literacy (0-17 points)</b>				
Group (experimental group) <sup>b</sup>	-1.15	1.05	1.19 (1)	.28
Time (posttest) <sup>c</sup>	0.13	0.23	0.34 (1)	.56
Group (experimental) $\times$ time (posttest) <sup>d</sup>	2.51	1.03	5.89 (1)	.02
<b>Communicative literacy (0-7 points)</b>				
Group (experimental group) <sup>b</sup>	-0.57	0.48	1.43 (1)	.23
Time (posttest) <sup>c</sup>	0.31	0.28	1.29 (1)	.26
Group (experimental) $\times$ time (posttest) <sup>d</sup>	1.26	0.51	6.17 (1)	.01
<b>Functional literacy (0-5 points)</b>				
Group (experimental group) <sup>b</sup>	-0.08	0.42	0.04 (1)	.85
Time (posttest) <sup>c</sup>	-0.25	0.21	1.46 (1)	.23
Group (experimental) $\times$ time (posttest) <sup>d</sup>	0.39	0.45	0.75 (1)	.39
<b>Critical literacy (0-5 points)</b>				
Group (experimental group) <sup>b</sup>	-0.50	0.39	1.65 (1)	.20
Time (posttest) <sup>c</sup>	-0.06	0.26	0.06 (1)	.81
Group (experimental) $\times$ time (posttest) <sup>d</sup>	0.99	0.42	5.68 (1)	.02
<b>CKD-specific disease knowledge (0-13 points)</b>				
Group (experimental group) <sup>b</sup>	-0.54	0.47	1.33 (1)	.25
Time (posttest) <sup>c</sup>	-0.38	0.28	1.82 (1)	.18
Group (experimental) $\times$ time (posttest) <sup>d</sup>	1.66	0.48	11.76 (1)	.001
<b>Basic knowledge (0-3 points)</b>				
Group (experimental group) <sup>b</sup>	-0.30	0.23	1.75 (1)	.19
Time (posttest) <sup>c</sup>	0.13	0.12	1.07 (1)	.30
Group (experimental) $\times$ time (posttest) <sup>d</sup>	0.30	0.23	1.75 (1)	.19
<b>Prevention (0-2 points)</b>				
Group (experimental group) <sup>b</sup>	0.07	0.06	1.07 (1)	.30
Time (posttest) <sup>c</sup>	0.07	0.06	1.07 (1)	.30
Group (experimental) $\times$ time (posttest) <sup>d</sup>	-0.07	0.06	1.07 (1)	.30
<b>Lifestyle (0-4 points)</b>				
Group (experimental group) <sup>b</sup>	-0.05	0.24	0.03 (1)	.85
Time (posttest) <sup>c</sup>	0.06	0.17	0.14 (1)	.70
Group (experimental) $\times$ time (posttest) <sup>d</sup>	0.30	0.25	1.36 (1)	.24
<b>Dietary intake (0- 2 points)</b>				
Group (experimental group) <sup>b</sup>	-0.02	0.13	0.02 (1)	.89
Time (posttest) <sup>c</sup>	-0.13	0.15	0.70 (1)	.40
Group (experimental) $\times$ time (posttest) <sup>d</sup>	0.27	0.18	2.30 (1)	.13
<b>Medication (0-2 points)</b>				

Variable	Coefficient ( $\beta$ )	SE	Wald $\chi^2$ (df)	P value
Group (experimental group) <sup>b</sup>	-0.23	0.15	2.32 (1)	.13
Time (posttest) <sup>c</sup>	-0.44	0.18	6.17 (1)	.01
Group (experimental) $\times$ time (posttest) <sup>d</sup>	0.80	0.22	13.32 (1)	<.001

<sup>a</sup>CKD: chronic kidney disease.

<sup>b</sup>Reference group (group): comparison group.

<sup>c</sup>Reference group (time): pretest.

<sup>d</sup>Reference group (group  $\times$  time): comparison group  $\times$  pretest.

The group differences in patterns of change over time shown in Table 2 also demonstrated that the experimental group had significant improvements in the scores for communicative literacy (coefficient=1.26, Wald  $\chi^2_1=6.17$ ;  $P=.01$ ) and critical literacy (coefficient=0.99, Wald  $\chi^2_1=5.68$ ,  $P=.02$ ) compared with the comparison group, but functional literacy did not significantly improve. Regarding CKD-specific disease knowledge, the experimental group showed significant improvement in medication (coefficient=0.80, Wald  $\chi^2_1=13.32$ ;  $P<.001$ ) compared with the comparison group, but there were no significant changes in areas such as basic knowledge, prevention, lifestyle, or dietary intake.

## Discussion

### Principal Findings

This study demonstrated preliminary evidence to support interactive robot-assisted virtual health coaching as an intervention tool for patients with CKD. Notably, participants in the experimental group showed significant improvements in both HL and disease knowledge compared with those in the comparison group. The experimental group was significantly younger than the comparison group, which may have influenced their receptiveness to the technology. However, prior studies indicate that older adults generally exhibit similar attitudes toward robots to those of younger individuals, challenging the stereotype of their lower robot-related receptiveness [29]. Furthermore, older adults often prefer human-like robots, such as the Kebbi robot, highlighting the importance of robot design and appearance in fostering acceptance [30,31]. These findings indicate that technology-enhanced educational interventions can effectively enhance HL and disease knowledge, which are associated with improved CKD-related outcomes.

The improvements observed in CKD-specific HL and disease knowledge were consistent with the benefits of technology-supported health education programs. Previous studies have shown that interactive digital interventions, particularly personalized coaching, can boost patient engagement and improve health outcomes [32,33]. This study builds on previous research by demonstrating the effectiveness of interactive robot-assisted virtual health coaching in managing chronic diseases. Our multidisciplinary approach included health professionals such as nephrologists and nurse practitioners, whose clinical experiences were integrated into the course content and represented by virtual health coaches [34]. Previous research has shown that avatar-based education has a positive

effect on patient engagement and HL, which aligns with our findings [35].

A literature review of digital health coaching for older workers highlighted how virtual health can support healthy aging [36]. Although said review focused on a different group, it showed that digital interventions could effectively enhance health knowledge and well-being, especially when adopting a user-centered approach. This aligns with the findings of our study, which designed the intervention using health care professionals' clinical experiences with patients. By integrating these real-world interactions, the digital tools were tailored to address the practical needs and circumstances of patients with CKD, making the content more relevant and applicable. These results underscore the importance of health care professionals' insights when developing effective digital health interventions.

Participants in the experimental group showed significant improvements in communicative and critical literacy following the intervention, whereas functional literacy was not significantly changed. This pattern is consistent with the findings of a previous study in the Netherlands, which found that communicative HL and critical HL were more influential on chronic disease self-management, whereas functional literacy was less impactful [37]. Furthermore, a recent cross-national study involving geriatricians from Europe and Japan highlighted that virtual health interventions could enhance HL, emotional well-being, and social engagement among older adults, emphasizing the benefits of personalized digital coaching [38]. Our findings suggest that interactive virtual health coaching successfully supported patients in comprehending and using health information, making informed decisions, and critically evaluating health messages. However, the lack of improvement in functional literacy may be attributed to the program's emphasis on enhancing communication, lifestyle modifications, and decision-making skills rather than basic skills such as reading medical documents or interpreting health indicators. Additionally, certain robot interface-related limitations may have impeded the delivery of more comprehensive health information necessary for developing functional skills. Future iterations should include more comprehensive content on functional skills to address all aspects of HL, thereby enhancing its overall effectiveness.

In addition to literacy, this study evaluated the effectiveness of the intervention on CKD-specific knowledge. The results showed a significant improvement in medication use in the experimental group, whereas no notable changes were observed in other areas such as basic knowledge, prevention, lifestyle, or



dietary intake. This suggests that the program's structured content was particularly effective for teaching patients about medication. The materials, designed by health care professionals based on their clinical experiences, incorporated visual aids and interactive discussions, making the content more engaging and easier to understand. This aligns with the findings of Occa et al [39], who highlighted that interactive features and visual informativeness help improve patient knowledge by enhancing cognitive absorption. Similarly, Hassan and Davies [40] found that virtual health tools improve medication adherence by boosting patient HL and reducing barriers, emphasizing convenience and empowerment. The limited improvement in other CKD-related knowledge areas may have been due to the small sample size, which may have affected the statistical significance of our findings. Additionally, some participants reported that similar topics had already been covered in educational brochures, which might have reduced their motivation to engage fully. A more comprehensive approach that places greater emphasis on prevention, lifestyle changes, and dietary guidance is required to address these areas better.

### Implications

This study has important implications for integrating digital health technologies into CKD education. Interactive robots, combined with a virtual health coaching program, have exhibited promise in enhancing HL and disease knowledge, particularly in resource-limited settings where health care resources are scarce and chronic disease management is challenging. By leveraging health care professionals' expertise and adhering to official health education guidelines, this study emphasizes the importance of creating standardized and engaging digital education tools that effectively meet patient education requirements. Furthermore, prior studies have demonstrated the potential of robots as impactful didactic tools in health science education, yielding promising results for enhancing cognitive therapies and facilitating health care intervention [41,42]. Expanding the use of such innovations may contribute to more effective patient education, improved disease knowledge, and enhanced HL, ultimately leading to improved CKD management.

### Limitations

Despite these promising findings, this study had several limitations. First, participants in the experimental group were significantly younger than those in the comparison group, partly due to recruitment challenges during the COVID-19 pandemic, which hindered the enrollment of a sufficient number of older

participants. Although age differences were controlled in the GEE analysis, which helped mitigate their impact, they remain a potential source of bias. Future research should further explore age-related differences, potentially incorporating multivariable analyses, to better understand and minimize their effects, ensuring the findings' broad applicability. This study primarily aimed to evaluate intervention effectiveness. Though digital literacy gaps related to age differences were not the primary focus, they represent an important area for future research.

The relatively small sample size limited the findings' generalizability, and 1-on-1 recruitment made larger sampling challenging. Statistical power was not explicitly considered during the study's design due to the lack of feasibility data, which accounts for the absence of a formal power calculation. Future studies should prioritize power analysis and incorporate larger sample sizes to confirm these results and enhance external validity. Additionally, the quasiexperimental design limited our ability to draw causal conclusions, suggesting that future research should use randomized controlled trials to strengthen causal inferences.

Another limitation involved the Taiwanese CKD population's unique characteristics, including dietary habits, medication use (eg, traditional Chinese medicine), and lifestyle factors, which may limit the findings' applicability to other populations. These cultural differences introduce potential biases, and future research should consider these factors to improve the results' generalizability.

### Conclusions

This study demonstrated that interactive robot-assisted virtual health coaching could potentially enhance CKD management by improving disease knowledge and HL. To our knowledge, this is the first study to use an interactive robot for CKD health education, presenting a novel approach that alleviates the burden on health care professionals. Developed by a multidisciplinary team, the program delivers standardized, credible education while engaging patients in their care. The findings emphasize the scalability of digital health solutions, particularly in resource-limited settings, offering a valuable tool for nephrology practices. Future research should validate these results across diverse populations, examine the long-term effects on HL and disease outcomes, and refine the intervention based on patient feedback to optimize its content and usability. Integrating digital tools into clinical practice could significantly advance patient education and chronic disease management.

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### Data Availability

The data sets generated or analyzed in this study are available from the corresponding author upon reasonable request.

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## Authors' Contributions

NJC participated in the design and coordination, formal analysis, and investigation; helped draft the manuscript; and read and approved the final version. CHC helped draft the manuscript and visualized, edited, and approved the final manuscript. CMH was a principal project leader, conceived the study, participated in design and coordination, and read and approved the final manuscript. FHL analyzed the data and conducted the formal analysis and investigation. LTL, KYL, CLL, and YCH participated in the design, formal analysis, and investigation. JLG was a principal project leader, conceived the study, participated in the design and coordination, and read and approved the final manuscript. All the authors read and agreed to the published version of this manuscript.

## Conflicts of Interest

None declared.

## References

1. Khosravi H, Das S, Al-Mamun A, Ahmed I. Binary Gaussian copula synthesis: a novel data augmentation technique to advance ML-based clinical decision support systems for early prediction of dialysis among CKD patients. arXiv. Preprint posted online on March 1, 2024. [doi: [10.48550/arXiv.2403.00965](https://doi.org/10.48550/arXiv.2403.00965)]
2. Lau DCW, Shaw E, McMullen S, Cowling T, Witges K, Amitay EL, et al. Acute and chronic complication profiles among patients with chronic kidney disease in Alberta, Canada: a retrospective observational study. *BMC Nephrol*. Jul 29, 2024;25(1):244. [FREE Full text] [doi: [10.1186/s12882-024-03682-z](https://doi.org/10.1186/s12882-024-03682-z)] [Medline: [39080608](https://pubmed.ncbi.nlm.nih.gov/39080608/)]
3. The National Health Insurance Statistics, 2022. National Health Insurance Administration, Ministry of Health and Welfare. URL: <https://www.nhi.gov.tw/en/cp-1302-5d3b4-213-2.html> [accessed 2024-12-31]
4. Hasannejadasl H, Roumen C, Smit Y, Dekker A, Fijten R. Health literacy and eHealth: challenges and strategies. *JCO Clin Cancer Inform*. Sep 2022;6:e2200005. [doi: [10.1200/CCI.22.00005](https://doi.org/10.1200/CCI.22.00005)] [Medline: [36194843](https://pubmed.ncbi.nlm.nih.gov/36194843/)]
5. Wei C, Shih C, Hsu Y, Chen Y, Yeh J, Shih J, et al. Development and application of a chronic kidney disease-specific health literacy, knowledge and disease awareness assessment tool for patients with chronic kidney disease in Taiwan. *BMJ Open*. Oct 11, 2021;11(10):e052597. [FREE Full text] [doi: [10.1136/bmjopen-2021-052597](https://doi.org/10.1136/bmjopen-2021-052597)] [Medline: [34635527](https://pubmed.ncbi.nlm.nih.gov/34635527/)]
6. Nutbeam D. The evolving concept of health literacy. *Soc Sci Med*. Dec 2008;67(12):2072-2078. [doi: [10.1016/j.socscimed.2008.09.050](https://doi.org/10.1016/j.socscimed.2008.09.050)] [Medline: [18952344](https://pubmed.ncbi.nlm.nih.gov/18952344/)]
7. Boonstra MD, Reijneveld SA, Foitzik EM, Westerhuis R, Navis G, de Winter AF. How to tackle health literacy problems in chronic kidney disease patients? A systematic review to identify promising intervention targets and strategies. *Nephrol Dial Transplant*. Dec 22, 2020;36(7):1207-1221. [FREE Full text] [doi: [10.1093/ndt/gfaa273](https://doi.org/10.1093/ndt/gfaa273)] [Medline: [33351936](https://pubmed.ncbi.nlm.nih.gov/33351936/)]
8. Shah JM, Ramsbotham J, Seib C, Muir R, Bonner A. A scoping review of the role of health literacy in chronic kidney disease self-management. *J Ren Care*. Dec 2021;47(4):221-233. [doi: [10.1111/jorc.12364](https://doi.org/10.1111/jorc.12364)] [Medline: [33533199](https://pubmed.ncbi.nlm.nih.gov/33533199/)]
9. Harrington M. Health literacy in children with chronic kidney disease and their caregivers. *Nephrol Nurs J*. 2015;42(1):53-56. [Medline: [26290918](https://pubmed.ncbi.nlm.nih.gov/26290918/)]
10. Lonie JM, Austin Z, Nguyen R, Gill I, Tsingos-Lucas C. Pharmacist-based health coaching: A new model of pharmacist-patient care. *Res Social Adm Pharm*. May 2017;13(3):644-652. [doi: [10.1016/j.sapharm.2016.06.015](https://doi.org/10.1016/j.sapharm.2016.06.015)] [Medline: [27497786](https://pubmed.ncbi.nlm.nih.gov/27497786/)]
11. Singh HK, Kennedy GA, Stupans I. Competencies and training of health professionals engaged in health coaching: A systematic review. *Chronic Illn*. Mar 16, 2022;18(1):58-85. [doi: [10.1177/1742395319899466](https://doi.org/10.1177/1742395319899466)] [Medline: [31948276](https://pubmed.ncbi.nlm.nih.gov/31948276/)]
12. An S, Song R. Effects of health coaching on behavioral modification among adults with cardiovascular risk factors: Systematic review and meta-analysis. *Patient Educ Couns*. Oct 2020;103(10):2029-2038. [doi: [10.1016/j.pec.2020.04.029](https://doi.org/10.1016/j.pec.2020.04.029)] [Medline: [32448627](https://pubmed.ncbi.nlm.nih.gov/32448627/)]
13. Teng H, Yen M, Fetzer S, Sung J, Hung S. Tailoring health-promoting programs for patients with chronic kidney disease: randomized controlled trial. *West J Nurs Res*. Mar 2021;43(2):138-150. [doi: [10.1177/0193945920942487](https://doi.org/10.1177/0193945920942487)] [Medline: [32698694](https://pubmed.ncbi.nlm.nih.gov/32698694/)]
14. Gc VS, Iglesias CP, Erdem S, Hassan L, Peek N, Manca A. Using discrete-choice experiments to elicit preferences for digital wearable health technology for self-management of chronic kidney disease. *Int J Technol Assess Health Care*. Oct 26, 2022;38(1):e77. [doi: [10.1017/S0266462322003233](https://doi.org/10.1017/S0266462322003233)] [Medline: [36286261](https://pubmed.ncbi.nlm.nih.gov/36286261/)]
15. Maddox T, Chmielewski C, Fitzpatrick T. Virtual reality in chronic kidney disease education and training. *Nephrol Nurs J*. 2022;49(4):329-381. [doi: [10.37526/1526-744X.2022.49.4.329](https://doi.org/10.37526/1526-744X.2022.49.4.329)] [Medline: [36054805](https://pubmed.ncbi.nlm.nih.gov/36054805/)]
16. Tsai Y, Hsiao P, Kuo M, Wang S, Chen T, Kung L, et al. Mobile health, disease knowledge, and self-care behavior in chronic kidney disease: a prospective cohort study. *J Pers Med*. Aug 27, 2021;11(9):1. [FREE Full text] [doi: [10.3390/jpm11090845](https://doi.org/10.3390/jpm11090845)] [Medline: [34575622](https://pubmed.ncbi.nlm.nih.gov/34575622/)]
17. Santini S, Galassi F, Kropf J, Stara V. A digital coach promoting healthy aging among older adults in transition to retirement: results from a qualitative study in Italy. *Sustainability*. Sep 09, 2020;12(18):7400. [doi: [10.3390/su12187400](https://doi.org/10.3390/su12187400)]
18. Helal S. Digital health: e-coaching and remote monitoring. *Computer*. Feb 2020;53(2):23-25. [doi: [10.1109/mc.2019.2958398](https://doi.org/10.1109/mc.2019.2958398)]

19. Ryan K, Dockray S, Linehan C. Understanding How eHealth Coaches Tailor Support For Weight Loss: Towards the Design of Person-Centered Coaching Systems. 2022. Presented at: CHI '22: CHI Conference on Human Factors in Computing Systems; April 29, 2022-May 5, 2022; New Orleans, LA. [doi: [10.1145/3491102.3501864](https://doi.org/10.1145/3491102.3501864)]
20. Venning A, Herd MC, Oswald TK, Razmi S, Glover F, Hawke T, et al. Exploring the acceptability of a digital mental health platform incorporating a virtual coach: The good, the bad, and the opportunities. *Health Informatics J.* Feb 18, 2021;27(1):1460458221994873. [FREE Full text] [doi: [10.1177/1460458221994873](https://doi.org/10.1177/1460458221994873)] [Medline: [33601947](https://pubmed.ncbi.nlm.nih.gov/33601947/)]
21. Taiwan Chronic Kidney Disease Clinical Guidelines. Taiwan Society of Nephrology. URL: <https://www.tsn.org.tw/guide.html> [accessed 2024-12-31]
22. Sannicandro K, De Santis A, Bellini C, Minerva T. A scoping review on the relationship between robotics in educational contexts and e-health. *Front. Educ.* Nov 2, 2022;7:1. [doi: [10.3389/feduc.2022.955572](https://doi.org/10.3389/feduc.2022.955572)]
23. Shih C, Chang T, Jensen DA, Chiu C. Development of a health literacy questionnaire for Taiwanese hemodialysis patients. *BMC Nephrol.* May 31, 2016;17(1):54. [FREE Full text] [doi: [10.1186/s12882-016-0266-y](https://doi.org/10.1186/s12882-016-0266-y)] [Medline: [27245160](https://pubmed.ncbi.nlm.nih.gov/27245160/)]
24. NUWA Robotics. URL: <https://www.nuwarobotics.com/en/product/> [accessed 2024-12-31]
25. Cheng Y, Wang Y, Cheng Y, Chen N. The impact of learning support facilitated by a robot and IoT-based tangible objects on children's game-based language learning. *Computer Assisted Language Learning.* Dec 05, 2022;37(7):2142-2173. [doi: [10.1080/09588221.2022.2152053](https://doi.org/10.1080/09588221.2022.2152053)]
26. Kostova S, Lekova A. Social Humanoid Robots as Assistive Technology for individuals with ASD - assessment of good practices. 2024. Presented at: CompSysTech '24: International Conference on Computer Systems and Technologies 2024; June 14-15, 2024; Ruse, Bulgaria. [doi: [10.1145/3674912.3674920](https://doi.org/10.1145/3674912.3674920)]
27. Huang T, Ishi H, Sato-shimokawara E, Yamaguchi T. Observation of robots with eifferent expressions on education application towards entrainment robots. *J. SOFT.* 2022;34(1):522-526. [doi: [10.3156/jsoft.34.1\\_522](https://doi.org/10.3156/jsoft.34.1_522)]
28. Chen N, Huang C, Fan C, Lu L, Lin F, Liao J, et al. User evaluation of a chat-based instant messaging support health education program for patients with chronic kidney disease: preliminary findings of a formative study. *JMIR Form Res.* Oct 19, 2023;7:e45484. [FREE Full text] [doi: [10.2196/45484](https://doi.org/10.2196/45484)] [Medline: [37725429](https://pubmed.ncbi.nlm.nih.gov/37725429/)]
29. Backonja U, Hall AK, Painter I, Kneale L, Lazar A, Cakmak M, et al. Comfort and attitudes towards robots among young, middle-aged, and older adults: a cross-sectional study. *J Nurs Scholarsh.* Dec 19, 2018;50(6):623-633. [FREE Full text] [doi: [10.1111/jnu.12430](https://doi.org/10.1111/jnu.12430)] [Medline: [30230692](https://pubmed.ncbi.nlm.nih.gov/30230692/)]
30. Tu Y, Chien S, Yeh S. Age-related differences in the uncanny valley effect. *Gerontology.* Jun 11, 2020;66(4):382-392. [doi: [10.1159/000507812](https://doi.org/10.1159/000507812)] [Medline: [32526760](https://pubmed.ncbi.nlm.nih.gov/32526760/)]
31. Fung KY, Lee LH, Sin KF, Song S, Qu H. Correction: Humanoid robot-empowered language learning based on self-determination theory. *Educ Inf Technol.* Sep 23, 2024;1. [doi: [10.1007/s10639-024-13054-7](https://doi.org/10.1007/s10639-024-13054-7)]
32. Rowsell A, Muller I, Murray E, Little P, Byrne CD, Ganahl K, et al. Views of people with high and low levels of health literacy about a digital intervention to promote physical activity for diabetes: a qualitative study in five countries. *J Med Internet Res.* Oct 12, 2015;17(10):e230. [FREE Full text] [doi: [10.2196/jmir.4999](https://doi.org/10.2196/jmir.4999)] [Medline: [26459743](https://pubmed.ncbi.nlm.nih.gov/26459743/)]
33. Campitelli A, Gills JL, Jones MD, Paulson S, Myers J, Bryk K, et al. The effect of a digital health coaching and health education protocol on cognition in adults at-risk for Alzheimer's. *Geroscience.* May 17, 2023;45(2):1147-1159. [FREE Full text] [doi: [10.1007/s11357-022-00711-3](https://doi.org/10.1007/s11357-022-00711-3)] [Medline: [36527582](https://pubmed.ncbi.nlm.nih.gov/36527582/)]
34. Blandford A, Gibbs J, Newhouse N, Perski O, Singh A, Murray E. Seven lessons for interdisciplinary research on interactive digital health interventions. *Digit Health.* 2018;4:2055207618770325. [FREE Full text] [doi: [10.1177/2055207618770325](https://doi.org/10.1177/2055207618770325)] [Medline: [29942629](https://pubmed.ncbi.nlm.nih.gov/29942629/)]
35. Tongpeth J, Du HY, Clark RA. Development and feasibility testing of an avatar-based education application for patients with acute coronary syndrome. *J Clin Nurs.* Oct 30, 2018;27(19-20):3561-3571. [doi: [10.1111/jocn.14528](https://doi.org/10.1111/jocn.14528)] [Medline: [29777554](https://pubmed.ncbi.nlm.nih.gov/29777554/)]
36. Stara V, Santini S, Kropf J, D'Amen B. Digital health coaching programs among older employees in transition to retirement: systematic literature review. *J Med Internet Res.* Oct 24, 2020;22(9):e17809. [FREE Full text] [doi: [10.2196/17809](https://doi.org/10.2196/17809)] [Medline: [32969827](https://pubmed.ncbi.nlm.nih.gov/32969827/)]
37. Heijmans M, Waverijn G, Rademakers J, van der Vaart R, Rijken M. Functional, communicative and critical health literacy of chronic disease patients and their importance for self-management. *Patient Educ Couns.* Jan 2015;98(1):41-48. [doi: [10.1016/j.pec.2014.10.006](https://doi.org/10.1016/j.pec.2014.10.006)] [Medline: [25455794](https://pubmed.ncbi.nlm.nih.gov/25455794/)]
38. Stara V, Soraci L, Takano E, Kondo I, Möller J, Maranesi E, et al. Intrinsic capacity and active and healthy aging domains supported by personalized digital coaching: survey study among geriatricians in Europe and Japan on eHealth opportunities for older adults. *J Med Internet Res.* Oct 12, 2023;25:e41035. [FREE Full text] [doi: [10.2196/41035](https://doi.org/10.2196/41035)] [Medline: [37824183](https://pubmed.ncbi.nlm.nih.gov/37824183/)]
39. Occa A, Morgan SE, Peng W, Mao B, McFarlane SJ, Grinfeder K, et al. Untangling interactivity's effects: The role of cognitive absorption, perceived visual informativeness, and cancer information overload. *Patient Educ Couns.* May 2021;104(5):1059-1065. [FREE Full text] [doi: [10.1016/j.pec.2020.10.007](https://doi.org/10.1016/j.pec.2020.10.007)] [Medline: [33969824](https://pubmed.ncbi.nlm.nih.gov/33969824/)]
40. Hassan A, Davies N. Expert insight into the use of eHealth interventions to aid medication adherence during COVID-19. *Patient Prefer Adherence.* 2024;18:721-731. [FREE Full text] [doi: [10.2147/PPA.S437822](https://doi.org/10.2147/PPA.S437822)] [Medline: [38529042](https://pubmed.ncbi.nlm.nih.gov/38529042/)]

41. Marcos-Pablos S, García-Peñalvo FJ. More than surgical tools: a systematic review of robots as didactic tools for the education of professionals in health sciences. *Adv Health Sci Educ Theory Pract*. Oct 30, 2022;27(4):1139-1176. [[FREE Full text](#)] [doi: [10.1007/s10459-022-10118-6](https://doi.org/10.1007/s10459-022-10118-6)] [Medline: [35771316](https://pubmed.ncbi.nlm.nih.gov/35771316/)]
42. Ashwini B, Narayan V, Bhatia A, Shukla J. Responsiveness towards robot-assisted interactions among pre-primary children of Indian ethnicity. 2021. Presented at: 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN); August 8-12, 2021; Vancouver, BC, Canada. [doi: [10.1109/ro-man50785.2021.9515520](https://doi.org/10.1109/ro-man50785.2021.9515520)]

## Abbreviations

**CKD:** chronic kidney disease

**GEE:** generalized estimating equations

**HL:** health literacy

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